S. B. Rindert

FIFTEEN YEARS OF OZONE OBSERVATIONS AT UPPSALA

Comments on Reports Nos. 23, 36 and 43

Department of Meteorology
Report No. 44

Department of Meteorology
University of Uppsala
Uppsala 1975

FIFTEEN YEARS OF OZONE OBSERVATIONS AT UPPSALA

BY

S. B. RINDERT

Fil. lic.

Norrlands

DOCTORAL DISSERTATION
TO BE PUBLICLY EXAMINED (IN ENGLISH)
IN THE LECTURE HALL OF THE DEPARTMENT OF METEOROLOGY,
UPPSALA UNIVERSITY,
ON SEPTEMBER 29, 1975, AT 10 A.M.,
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY
(ACCORDING TO ROYAL PROCLAMATION NO. 327, 1969)

Uppsala 1975

Digitized by the Internet Archive
in 2026

https://archive.org/details/IA41548926_0042

S. B. Rindert

FIFTEEN YEARS OF OZONE OBSERVATIONS AT UPPSALA

Comments on Reports Nos. 23, 36 and 43

Department of Meteorology
Report No. 44

Department of Meteorology
University of Uppsala
Uppsala 1975

LANDSTINGETS VERKSTÄDER UPPSALA 1975

UNIV.
LEIDEN
BIBL.

FIFTEEN YEARS OF OZONE OBSERVATIONS AT UPPSALA

Comments on Reports Nos. 23, 36 and 43

By S. B. Rindert

Department of Meteorology, University of Uppsala, Sweden

The ozone observations carried out at Uppsala from 1951 to 1966 have been discussed in the following reports from the Department of Meteorology.

Report No. 23. *Testing and calibrating the Dobson ozone spectrophotometer No. 30.* 1971.

Abstract. Measurements of atmospheric ozone were carried out at Uppsala, Sweden, from 11 May 1951 to 19 July 1966. The present paper contains an analysis of the test results and the ozone measurements, in accordance with the International Ozone Commission (IOC) recommendations. The ozone spectrophotometer , the theories involved and the main methods of observation are also considered. The report is primarily intended for other research workers who may be interested in the question of the reliability of the deduced total amounts of ozone, a report on which is to be presented later.

Report No. 36. *Constructing empirical blue-sky ozone charts.* 1973.

Abstract. A method of preparing empirical ozone charts by using smoothed group mean values of N/μ or N for defined intervals of μ is presented, together with charts for all pairs and double pairs of wavelengths, based upon measurements of the total amount of atmospheric ozone at Uppsala during the period 1951 to 1966. The charts are tested and the accuracy of the various parts is assessed by means of error frequencies.

Report No. 43. *Observations of the total amount of atmospheric ozone at Uppsala, Sweden, from 1951 to 1966.* 1975.

Abstract. The present report contains a thorough analysis of the accuracy of the different types of observation used when measuring the total amount of ozone by means of the Dobson spectrophotometer. This information forms the basis of priorities and rules for the ozone calculations in this investigation. The resulting final ozone data representing individual observations as well as daily means during the long period of ozone observations at Uppsala are presented. The report also contains comments on the accuracy of the empirical charts published in the preceding report on this subject (No. 36).

---

1. INTRODUCTION

The daily routine observations of atmospheric ozone at Uppsala, Sweden, began on 11 May 1951 and were discontinued on 17 July 1966.

The ozone observations were carried out by individual observers and, to start with, at arbitrary times. These non-systematic observations were also characterized by differing procedures. During the first years direct sunlight (DS) and zenith sky (ZB and ZC) observations were mainly restricted to the wavelength pair C of the spectrophotometer. From the middle of 1953 onwards observations were generally made using all standard pairs of wavelengths (A, B, C and D). The scarcity of useful observations during the winter months is a specially regrettable source of trouble. These circumstances make the treatment of the ozone data somewhat difficult in many respects. There is no doubt that more systematic observations such as those recommended by the IOC in connection with the preparations for the International Geophysical Year (IGY) [1] would have been a substantial advantage particularly when treating the observations from a statistical point of view.

In the main observations were concentrated to the daylight period and aimed at determining the total amount of ozone. Some observations of the vertical distribution of ozone by means of the Umkehr method [2,3] were made but rather sporadically. The nocturnal observations using moonlight were very few in number and have not been considered at all in this study.

For extended periods measurements were made only once per day near local apparent noon. The reasons for this most unfortunate state of affairs were due to personal as well as financial difficulties.

When ozone observations commence at an observing station all background data are preliminary. This is the case for instrument constants as well as for empirical zenith charts. A preliminary test of the ozone spectrophotometer was carried out by the manufacturer, in this case Messrs. R. & J. Beck, Ltd., London. Not until a rather long series of observations has been made is it possible to determine more adequate instrument constants and empirical charts [4,5]. This also means that ozone data published in the meantime are tentative and therefore subject to future revision.

The treatment of the Uppsala ozone observations was carried out in the following manner. To begin with the spectrophotometer was analysed and all tests and calibrations were studied. By this procedure all constants involved in the basic equations used in calculating the total amount of ozone in the atmosphere were finally assessed. The next step was to construct the empirical blue-sky charts

required for calculating the amount of ozone on occasions for which direct solar observations are not available. Then the accuracy of the different types of direct solar and zenith sky observations were determined. These results were then used to obtain priorities and rules for the final step, that is the calculation of the total amount of atmospheric ozone from the entire body of ozone observations at Uppsala during the period 1951 to 1966.

2. THE ABSORPTION COEFFICIENTS OF OZONE

A special complication when using data from different stations and for different periods is that the values of the adopted absorption coefficients of ozone were changed several times in the course of time (Table 1). As far as the Uppsala pe-

Table 1. *Absorption coefficients of ozone and atmospheric corrections adopted during different periods* [6,7]. The scattering coefficients due to air molecules are derived from the Rayleigh-Cabannes formula [4].

Pair of wavelengths	$(\alpha - \alpha')_i$			$\frac{(\beta - \beta')_i}{(\alpha - \alpha')_i}$		
	Before 1 July 1957 (Ny and Choong)	1 July 1957 to 31 Dec. 1967 (Vigroux)	From 1 Jan. 1968 (Vigroux and Dobson)	Before 1 July 1957	1 July 1957 to 31 Dec. 1967	From 1 Jan. 1968
A	2.42	1.762	1.748	0.047	0.066	0.066
B	1.65	1.223	1.140	0.068	0.092	0.099
C	1.15	0.865	0.800	0.095	0.127	0.137
D	0.52	0.374	0.360	0.200	0.278	0.289

riod is concerned such a fundamental change took place on 1 July 1957 [6], that is on the very first day of the IGY. As the table shows a lesser change was made on 1 January 1968 [7], in this case when the Uppsala observation series had already been discontinued.

In IOC Circular No. 0.4 [6] the following recommendation is made for treating observations of past years: "In most comparisons with observations of past years it will be sufficient to select a mean value of the conversion factor. Unless special circumstances demand other treatment we suggest the general use of the approximate factor 1.36 to convert from old (Ny Tsi Ze) levels to the new (Vigroux) levels of ozone amounts".

Table 2. *Conversion factors for ozone data from past periods to current levels of ozone amounts.* Those based on observational data also contain standard deviations.

Period	Ratio	Wavelengths									
		A	B	C	D	AD	AC	BD	AB	BC	CD
Before 1 July 1957	Old to current abs. coeff.	1.384	1.447	1.438	1.444	1.369	1.340	1.449	1.266	1.471	1.432
	From observational data	1.382	1.445	1.435	1.444	1.366	1.336	1.446	1.263	1.469	1.429
		0.014	0.016	0.016	0.024	0.014	0.014	0.016	0.011	0.016	0.016
1 July 1957 to 31 Dec. 1967	Old to current abs. coeff.	1.008	1.073	1.081	1.039	1.000	0.946	1.088	0.887	1.053	1.116
	From observational data	1.010	1.071	1.082	1.038	1.002	0.948	1.085	0.894	1.042	1.118
		0.005	0.004	0.002	0.008	0.006	0.005	0.005	0.006	0.008	0.009

For comparison purposes the same observational data used when discussing the accuracy of DS observations in Report No. 43 (1197 observations) have been used to determine the conversion factors for different observation periods. The results are given in Table 2, which also contains ratios of old to current values of absorption coefficients of ozone.

Through the present investigation it has been possible to calculate the total amounts of ozone for the entire period of observations at Uppsala making use of *the current absorption coefficients of ozone* (valid from 1 January 1968). This is in accordance with the main objective of this work which has been to produce a final result of homogeneous and consistent total ozone data.

3. THE DOBSON OZONE SPECTROPHOTOMETER NO. 30

The Uppsala spectrophotometer was housed in a laboratory and had to be moved 25 m or so outdoors when making an observation. On rare occasions in early spring and late autumn observations were made through an open window in the workshop of the Department.

There have of course been operational and instrumental troubles from time to time. But these are only what would be expected during a long series of routine obser-

vations. We have been spared such troubles as severe contamination of the optical parts of the spectrophotometer due to soot, oil or dust from the rectifier unit, jarring of one kind or another when moving the instrument, instrument mishaps such as sections of the optical wedges loosened from their holders, scratches on mirror-surfaces, heavy overexposure of the photomultiplier, or malfunction of the wavelength dials, shutter motor or mechanical rectifier as reported from a number of other ozone stations [8-11].

A real difficulty at very low outdoor temperatures was the rapid cooling of the instrument despite the cover furnished by the manufacturer. On these occasions the instrument ceased to function for several hours.

According to Dobson [12] one of the basic aims in constructing the spectrophotometer was to be able to measure the total amount of ozone with an error of less than about one percent. There is no doubt that this condition can be achieved provided that the instrument is handled by qualified personnel. But it is also clear that it is impossible to maintain a high observation quality if the ozone observations are carried out by ordinary synoptic weather observers. This system was tried at our Department when the spectrophotometer was moved to our observatory at Marsta. The result was unsatisfactory, to say the least, and does not invite repetition. The ozone instrument is complicated and therefore should be handled by people with at least a basic knowledge of physics and instrumentation.

It is improbable that the changes detected by the various instrument tests appreciably affected calculations of the total amounts of ozone. The general reliability of Uppsala ozone data is confirmed by the analysis of the accuracy of ozone observations presented in Report No. 43.

The main objection to the results presented in Report No. 23 is probably the unsatisfactory number of tests made over the years. This is particularly the case regarding the first years of the observation period. Unfortunately it was not possible to locate the test forms from this initial period. Neither was it possible to obtain the forms containing the original tests carried out at Shotover, Oxford, in 1949, which are now kept at the British Meteorological Office in London.

One of the main conclusions of Report No. 23 has been disregarded at later stages of the present study. The longterm values of the instrumental constant S_i have been replaced by *the annual means* (Fig. 1). In this way the average accuracy when calculating the total amounts of ozone has been much improved.

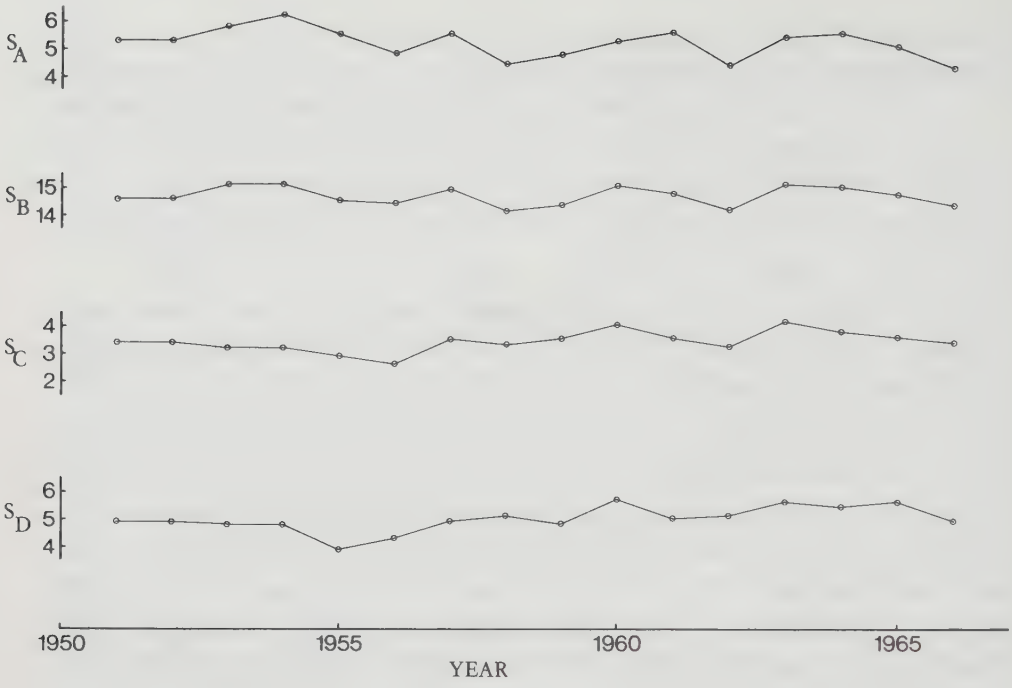

Fig. 1. *Annual means of S_i for DS observations.* This diagram corresponds to Table 3, Report No. 43.

Table 3 shows a comparison between the standard deviations of S_i obtained when determining the longterm values of S_i at Uppsala and the values obtained at Oxford during a period of fine weather in the spring and summer of 1957 [13]. The Uppsala values are based on 277 half days, those for Oxford on 17. The table shows that the Uppsala values are less variable than the Oxford values, excepting the A wavelengths, despite the fact that the Uppsala material is subjected to far fewer restrictions than that for Oxford.

Report No. 23 contains certain information with reference to computor processing

Table 3. *Standard deviations of the instrument constant S_i.* Uppsala: $\mu \leqslant 4.0$, $\delta \cos z \geqslant 0.2$, 277 half days. Oxford: $\mu \simeq$ 1.2 and 1.9, $\delta \cos z \simeq 0.3$, 17 half days.

Wavelengths	Uppsala	Oxford
A	3.8	3.2
B	2.6	3.0
C	1.9	2.0
D	1.5	1.8

of data in connection with *determinations of relative path-lengths* in the atmosphere (cos z, m and μ). This information has been included in order to help other research workers who might carry out an analysis similar to that presented in the above-mentioned report.

4. THE EMPIRICAL BLUE-SKY OZONE CHARTS

Each Dobson ozone spectrophotometer is supplied with empirically constructed zenith blue-sky charts for C and AD wavelengths. These charts are based on observa-

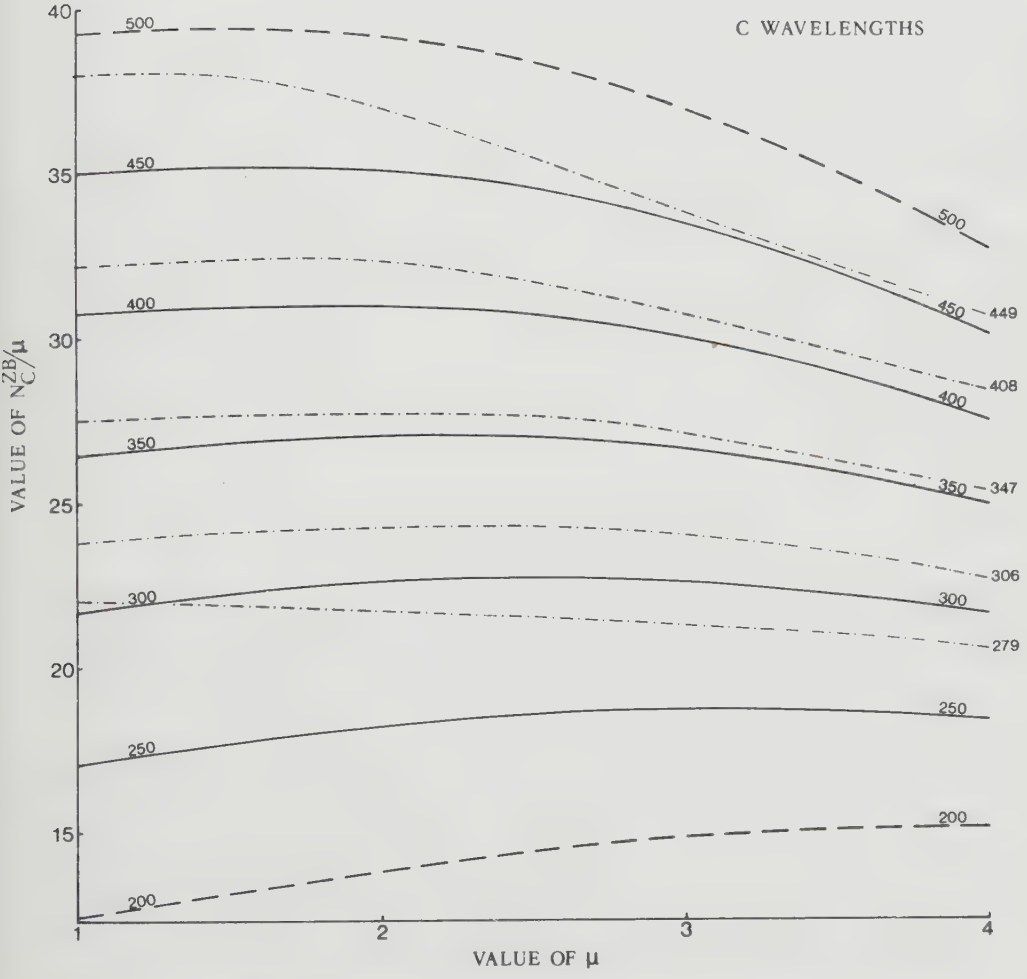

Fig. 2. *The empirical zenith blue-sky chart for C wavelengths.* The final Uppsala chart: ——, – – – . The Oxford chart supplied: -·-·-. The ozone values of the Oxford chart are multiplied by 1.36 to allow for changes in absorption coefficients of ozone. Unit: matm cm.

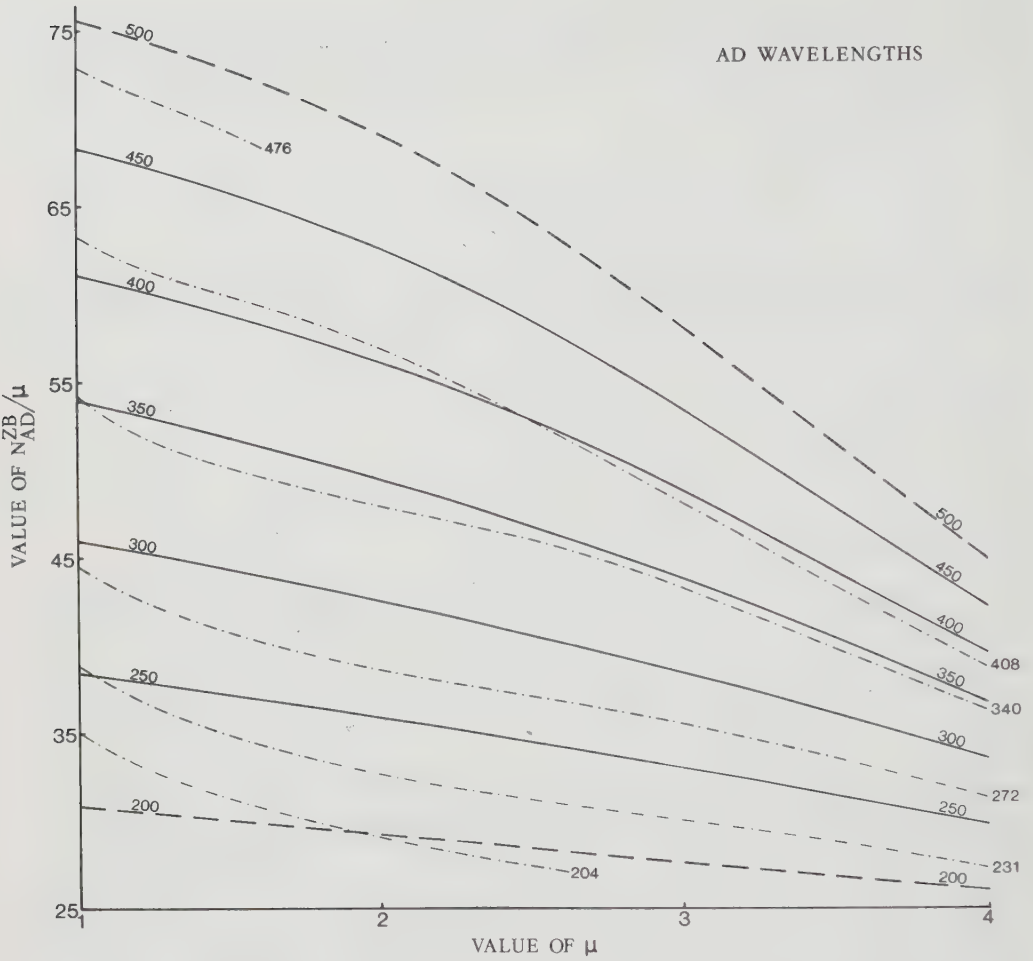

Fig. 3. *The empirical zenith blue-sky chart for AD wavelengths.* The final Uppsala chart: ——— , – – – . The Oxford chart supplied (Spectrophotometer No. 1, August 1953): —·—·—. The ozone values of the Oxford chart are multiplied by 1.36 to allow for changes in absorption coefficients of ozone. Unit: matm cm.

tions carried out at Oxford where the vertical distribution of ozone may differ from that at the ozone station concerned. It is therefore necessary to make appropriate corrections in order to bring ozone values calculated from ZB observations into accordance with the level corresponding to DS-AD observations [14] at the actual locality [15]. Figures 2 and 3 show comparisons between the Oxford charts received and the final Uppsala charts.

ZB observations carried out when the sun is very low are not very reliable for obtaining the total amount of ozone because the readings depend not only on the

total ozone but also on its vertical distribution. In Report No. 43 it was pointed out that the empirical blue-sky ozone charts for the double pairs of wavelengths when $\mu > 4$ were not suitable for calculating the total amount of ozone due to insufficient accuracy. These curves are therefore only of theoretical interest.

The accuracy of the empirical charts published in Report No. 36 was assessed by using the longterm values of S_i. In Report No. 43 these charts were reexamined using *the annual means* of S_i. In this way the accuracy was much improved, particularly for $\mu < 4$.

5. THE CC´ AND AD CLOUD METHODS

Figs. 4 and 5 in Report No. 43 show average differences in the amount of ozone calculated by means of the CC´ and AD cloud methods at different values of μ for high, middle and low clouds. The close relation between these two methods seems to exist up to at least $\mu = 4.5$, which is a rather unexpected result.

According to the IOC recommendations [4] the AD cloud method is preferable when $\mu < 2.5$. This is confirmed by Table 13, Report No. 43, only as far as *high clouds* are concerned. For middle and low clouds AD and CC´ cloud methods show practically the same accuracy. When $\mu = 2.5 - 3.5$ the CC´ method is slightly better than the AD method for all types of cloud. At still higher values of μ the pattern is more irregular probably due to the very few observations available here.

6. THE FINAL TOTAL OZONE DATA

Report No. 43 contains a thorough analysis of the accuracy of the different types of observations used to determine the total amount of ozone in the atmosphere. In Table 4 is presented a comparison between the Uppsala results and those obtained at some other ozone stations [9-11,13]. The above-mentioned report also contains a *priority table* which can be consulted on occasions when the recommended DS-AD observation is not available. *Which* type of observation shall represent the amount of ozone in such a case cannot be discovered by studying the IOC instructions [16]. This state of affairs may be further exemplified by the following quotation from a paper by Dütsch [17] relating to the calculation of daily means: "If there are several different types of observation, the daily means should be computed from AD readings taken with the ground quartz plate only, provided that not all of these are apparently unreliable; for example, cloudy sky observations should not be included in the same mean with good direct sun observations. If no reliable

Table 4. *The accuracy of different types of observations for several ozone stations.* The accuracy is expressed in error frequencies (⩽ 1 %, ⩽ 2 %, etc.) or standard deviations. In some cases the interval of μ, the type of reference ozone values and the number of observations are given. The Uppsala zenith blue-sky observations are not corrected for haze.

Ozone station		Type of observation				
		DS-AD	ZB-AD	ZB-CC′	ZC-AD	ZC-CC′
Uppsala	Long-term values of S_i		μ = 1 – 4 x/DS-AD = 250-450 1102 observations 29-64-85-94	μ = 1 – 4 x/DS-AD = 250-450 1107 observations 24-44-62-77		
	Annual values of S_i		μ = 1 – 4 x/DS-AD 1197 observations 65-91-99-100	μ = 1 – 4 x/DS-AD 1197 observations 35-59-77-88		
		μ = 1 – 4 All ozone values 1197 observations 2.0	μ = 1 – 4 All ozone values 1197 observations 3.5	μ = 1 – 4 All ozone values 1197 observations 9.4	μ = 1 – 2.5 HC 6.9 MC 11.1 } 10.9 LC 13.7	μ = 1 – 2.5 HC 10.0 MC 11.2 } 11.9 LC 14.0
Oxford		40 pairs of obs. 3	4	5	x/DS-AD(< 3 hours) 10 8.5	x/DS-AD(< 3 hours) 10 8.5
Moosonee			Wide range in μ x/DS-AD 177 observations 54-78-95	x/DS-AD 201 observations 60-82-92	μ = 1.1 – 2.4 x/DS-AD(< 3 hours) 136 observations 32-55-76-91	x/DS-AD,ZB-AD,ZC-AD 300 observations 33-66-81-89
Resolute			x/DS-AD 126 observations 47-72-96			
Edmonton			x/DS-AD > 750 observations 70-91-97-99	x/DS-AD Nearly 500 obs. 47-73-90-96	x/DS-AD 239 observations 41-72-88-93	All types of x 263 observations 69-81-91-95

direct sun AD measurements are available, the other types of observation used in the calculation of the mean should be indicated".

An ozone observer needs more specific instructions. The priority table of Report No. 43 offers this form of guidance. This type of table is therefore a prerequisite for obtaining internally consistent ozone data.

The results in Table 4 may be compared with the very high accuracy of observation which it is possible to attain at an ozone station such as Mauna Loa on Hawaii [18]. The observatory at Mauna Loa is situated in the Pacific high pressure area and is located on the north slope of Mauna Loa Volcano, about 6 km from the summit, at a height of 3400 m. This low-latitude station has an excellent climate for making ozone observations. The day-to-day variation in ozone is very small and due to the high altitude the atmosphere is very clear. Table 5 shows the average differences in the amount of ozone calculated from DS-AD observations made at various intervals of time [13].

Table 5. Average differences in ozone as a function of time for DS-AD observations at Mauna Loa (Hawaii) in May, June and July 1958.

Interval of time (t) (hours)	$\sqrt{t}$	Average difference in ozone (matm cm)
1	1.0	1.7
4	2.0	2.8
9	3.0	3.8
11	3.3	4.1
13	3.6	4.3
15	3.9	4.5

The results of the last two columns are presented in Figure 4. If the curve through the plotted points is extrapolated back to the zero time interval the value 1.0 matm cm is obtained. This very small value then represents the probable difference between two almost simultaneous ozone observations.

7. SOME CONCLUDING REMARKS

The ozone data presented in Reports Nos. 23, 36 and 43 are not considered here from the standpoint of their meteorological significance. These reports are primarily intended for research workers at other ozone stations who are interested in the reliability of the results published. They also illustrate the method of

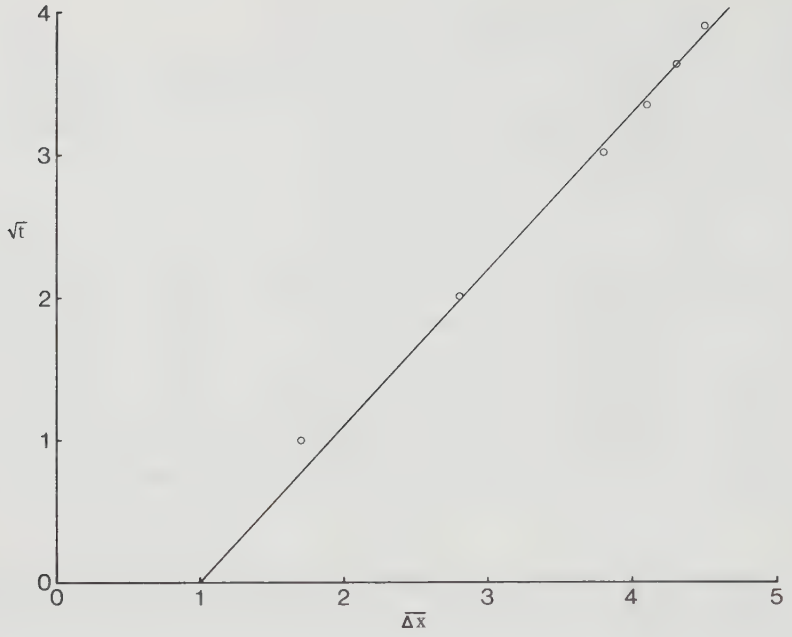

Fig. 4. Average differences in ozone as a function of the square-root of time for DS-AD observations at Mauna Loa (Hawaii) in May, June and July 1958.

treating a comprehensive ozone material after breaking off the series of observations and the attempts to attain the highest possible accuracy in the final body of ozone data published.

The fundamental result of the present study is therefore a *homogeneous final data material* which for quite natural reasons, in a positive manner, differs from the preliminary Ozone Data for the World published bi-monthly by the Canadian Meteorological Service in co-operation with the World Meteorological Organization (WMO). In this respect the Uppsala final total ozone data must be regarded as rather unique. It is hoped that those in charge of other ozone stations will be encouraged to make a similar analysis of their observations despite the great amount of work required.

The final ozone data presented in Report No. 43 should replace all earlier data published in ozone literature from the Uppsala station.

ACKNOWLEDGEMENTS

I am grateful to Prof. G. H. Liljequist for his interest and unfailing support at all stages of this study.

I am indebted to Mr. L. Enger for performing the calculations and Mr. W. Barrett for revising the English text.

Acknowledgement is also due to the Swedish Natural Science Research Council (Statens naturvetenskapliga forskningsråd) for financial support.

REFERENCES

[1] G. M. B. Dobson and C. W. B. Normand, Times of routine ozone measurements IGY, IOC Circular No. 0.2, Ann. IGY, 5, pp. 86-87, 1957.

[2] H. Taba, Ozone observations and their meteorological applications, WMO Technical Note No. 36, Geneva, 1961.

[3] G. M. B. Dobson and C. W. B. Normand, Götz Umkehr observations during IGY using ozone spectrophotometers, IOC Circular No. 0.3, Ann. IGY, 5, pp. 88-89, 1957.

[4] G. M. B. Dobson, Observers´ handbook for the ozone spectrophotometer, Ann. IGY, 5, pp. 46-81, 1957.

[5] G. M. B. Dobson, Adjustment and calibration of the ozone spectrophotometer, Ann. IGY, 5, pp. 90-114, 1957.

[6] G. M. B. Dobson and C. W. B. Normand, Revision of values of coefficients of ozone absorption and of atmospheric scattering, IOC Circular No. 0.4, 5th July 1957.

[7] WMO Circular Letter No. 12.835/T/ALO of 15 May, 1968, Annex.

[8] R. F. Sturrock, Measurements of atmospheric ozone during the International Geophysical Year at Alert, N. W. T. (82^{o} 30´N., 62^{o} 20´W.). Canadian Meteorological Memoirs, No. 4, Meteorological Branch, Department of Transport, Toronto, 1960.

[9] W. D. Komhyr, Measurements of atmospheric ozone at Moosonee, Canada, July 1, 1957, to July 31, 1960. Canadian Meteorological Memoirs, No. 6, Meteorological Branch, Department of Transport, Toronto, 1961.

[10] H. M. Sullivan, W. D. Komhyr and C. L. Mateer, Measurements of atmospheric ozone at Resolute, Canada, 74^{o} 43´N., 94^{o} 59´W., July 7, 1957, to December 31, 1959. Canadian Meteorological Memoirs, No. 7, Meteorological Branch, Department of Transport, Toronto, 1961.

[11] J. J. Kinisky, W. D. Komhyr and C. L. Mateer, Measurements of atmospheric ozone at Edmonton, Canada, 53^{o} 34´N., 113^{o} 31´W., July 1, 1957, to June 30, 1960. Canadian Meteorological Memoirs, No. 8, Meteorological Branch, Department of Transport, Toronto, 1961.

[12] G. M. B. Dobson, Forty years´ research on atmospheric ozone at Oxford: A history. Memorandum No. 66.1, University of Oxford, 1966.

[13] G. M. B. Dobson and C. W. B. Normand, Determination of constants etc. used in the calculation of the amount of ozone from spectrophotometer measurements and an analysis of the accuracy of the results, IAMAP, Oct. 1958.

[14] G. M. B. Dobson and C. W. B. Normand, To all observers in charge of ozone instruments, Ann. IGY, 5, pp. 82-83, 1957.

[15] G. M. B. Dobson and C. W. B. Normand, Analysis of ozone measurements made with the ozone spectrophotometer, IOC Circular No. 0.1, Ann. IGY, 5, pp. 84-85, 1957.

[16] WMO Circular Letter No. 15.637/T/DR of 15 November 1962, Annex.

[17] H. U. Dütsch, Measurement of atmospheric ozone, Ann. IQSY, Vol. 1, Ch. 15, App. 1, 1968.

[18] Catalogue of ozone stations, WMO/OMM – No. 127. TP. 57, 1962.

(Manuscript completed 2 June 1975)

Address of the author:

Universitetslektor Sven Birger Rindert
Department of Meteorology
Box 516, 75120 Uppsala 1
Sweden

Department of Meteorology Reports, University of Uppsala, Sweden

No. 1. Tage Andersson: Sveriges dimklimat (The fog climate of Sweden, with an English summary). 1965.

No. 2. Hans Odin och Kurt Perttu: Strålningsmätningar nära skogsgränsen i norra Sverige (Radiation measurements near the forest limit in northern Sweden, with an English summary). 1966.

No. 3. Eugen Ungethüm: Measurements of the electric field in the free atmosphere during IQSY 1964-1965. 1966.

No. 4. Eugen Ungethüm: Eine neue Radiosonde zur Messung des luftelektrischen Feldes in der freien Atmosphäre. 1967.

No. 5. Sven Israelsson: Om den naturliga luftradioaktivitetens variation i marknära skikt (On the variation of the natural radioactivity in the air near the ground, with an English summary). 1968.

No. 6. Tor Bergeron: Studies of the oreigenic effects on the areal fine structure of rainfall distribution. 1968.

No. 7. Tage Andersson: On the representativity of rain measurements. 1968.

No. 8. Tage Andersson: Nederbördens halt av föroreningar i och omkring Uppsala under juli-oktober 1962 (The contamination of precipitation in the Uppsala region during July-October 1962, with an English summary). 1968.

No. 9. Tage Andersson: Stockholmstraktens dimklimat (The fog climate of the Stockholm region, with an English summary). 1968.

No. 10. Eugen Ungethüm: VLF-Strahlung der Atmosphäre. Messstationen Uppsala-Stockholm. Aufbau und Resultate 1968. 1969.

No. 11. Sven Israelsson: Mätningar av den naturliga β-aktiviteten och de polära ledningsförmågorna i marknära skikt (Measurements of the natural β-activity and the atmospheric polar conductivity at ground level, with an English summary). 1969.

No. 12. Ann-Sofi Smedman: Solskenstid i Marsta, Uppsala, 1949-1967. 1969.

No. 13. Tage Andersson: Observations of temperature and precipitation in Sweden since the 1850´s. Part A. Observational methods and error sources. 1969.

No. 14. Tage Andersson: Stockholmstraktens nederbörd. 1969.

No. 15. Sven Israelsson: Conductivity and concentration of small ions in the air near the ground. 1970.

No. 16. S. Israelsson, E. Knudsen and E. Ungethüm: Ion-mobility distributions at ground level. 1970.

No. 17. Eugen Ungethüm: Jonen-Beweglichkeiten in Luft. 1970.

No. 18. Eugen Ungethüm: Measurements of the VLF-noise level. 1970.

No. 19. Tor Bergeron: Cloud-physics research and the future fresh-water supply of the world. 1970.

No. 20. Tor Bergeron: Mesometeorological studies of precipitation, IV. Oreigenic and convective rainfall patterns. 1970.

No. 21. Sven Israelsson, Edgar Knudsen and Eugen Ungethüm: Measurements of the β-activity in the air near the ground. 1970.

No. 22. Eugen Ungethüm: The relationship between high and low ion-mobility ranges. Experimental results. 1970.

No. 23. S. B. Rindert: Testing and calibrating the Dobson ozone spectrophotometer No. 30. 1971.

No. 24. S. Israelsson, E. Knudsen, E. Ungethüm and L. Enger: Meteorological influences upon the artificial β-activity of the atmosphere. 1971.

No. 25. L. Hedenmalm, S. Israelsson and E. Ungethüm: Natural β-activity in the air near the ground. Part A: On the diurnal variation of the natural β-activity in the air near the ground. 1971.

No. 26. S. Israelsson, E. Knudsen and E. Ungethüm: Natural β-activity in the air near the ground. Parts B - E. 1972.

No. 27. S. Israelsson, E. Knudsen and E. Ungethüm: Natural α-activity in the air near the ground. 1972.

No. 28. S. Israelsson, E. Knudsen and E. Ungethüm: Radon and thoron in the air near the ground. 1972.

No. 29. S. Israelsson, E. Knudsen and E. Ungethüm: On the variations of electric conductivity and small-ion density in the air near the ground. 1972.

No. 30. S. Israelsson, E. Knudsen and E. Ungethüm: Natural radioactivity in soil gas and exhalation of natural radioactivity from the ground surface. 1972.

No. 31. A-S. Smedman-Högström: Temperature and humidity spectra in the atmospheric surface layer. 1972.

No. 32. A-S. Smedman-Högström and U. Högström: The Marsta micro-meteorological field project. Profile measurement system and some preliminary data. 1972.

No. 33. A-S. Smedman-Högström: Spectra of wind, temperature and humidity over large frequency ranges. 1973.

No. 34. B. Dahlström: Investigation of errors in rainfall observations. A continued study. 1973.

No. 35. B. Dahlström: Error analysis of rainfall data by polynomials. A continued study. 1973.

No. 36. S. B. Rindert: Constructing empirical blue-sky ozone charts. 1973.

No. 37. Ulf Högström: Pattern of wet fallout of sulfurous pollutants emitted from a city during rain or snow. 1974.

No. 38. Tor Bergeron: Mesometeorological studies of precipitation, V. Monthly rainfall in the Uppsala-field. With a collection of annotated maps 1955-1965. 1973.

No. 39. C. O. Oluwafemi, E. Ungethüm, S. Israelsson, E. Knudsen and A. Hultberg: On the influence of eddy-motion on air-earth current density. 1974.

No. 40. C. O. Oluwafemi, E. Ungethüm, S. Israelsson and E. Knudsen: Correlation and spectrum properties of the potential gradient and space-charge density in the atmospheric surface layer. 1974.

No. 41. Ulf Högström: The Marsta micrometeorological field study. Measurements of turbulent fluxes. 1974.

No. 42. S. Israelsson, C. O. Oluwafemi and E. Ungethüm: Correlation and spectral studies of electric, radioactive and meteorological parameters under fair weather conditions in the atmospheric surface layer. Part A: Variations of atmospheric electrical parameters in the frequency range from 0.01 to 0.3 cycles per hour under fair weather conditions. 1975.

No. 43. S. B. Rindert: Observations of the total amount of atmospheric ozone at Uppsala, Sweden, from 1951 to 1966. 1975.

No. 44. S. B. Rindert: Fifteen years of ozone observations at Uppsala. Comments on Reports Nos. 23, 36 and 43. 1975.